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ON THE CORRELATION BETWEEN SOMATIC CHARACTERS AND FERTILITY. II.

ILLUSTRATIONS FROM PHASEOLUS VULGARIS

J. ARTHUR HARRIS

I. INTRODUCTORY REMARKS

The purpose of this paper, like that of the one which preceded it,¹ is the presentation of quantitative data toward the solution of the relationship between the degree of development of the somatic organs of the plant individual and its fertility.

The materials are drawn exclusively from pedigreed dwarf varieties of garden beans, *Phaseolus vulgaris*. These varieties are being described in biometric terms elsewhere, as shown in the bibliography; hence it is only necessary to designate the series by the key letters which open the detailed information of other papers.

The characters here treated are number of pods per plant, number of ovules formed per pod and number of seeds matured per pod.

II. ANALYSIS OF DATA

Table I shows the correlations, r_{po} , r_{ps} , and the partial correlation r_{ps} , when p = pods per plant, o = ovules per pod, s = seeds per pod. The actual number of plants and the number of pods counted are also entered. Because of the great bulkiness of the data it is not feasible to publish even in condensed form the 64 correlation tables from which these constants were deduced.²

The correlations of this table are also shown in diagram 1.

I turn first to the question of linearity of regression. This is essential statistically, since upon the distribution of the means of the arrays of ovules or seeds in a sensibly straight line depends the va-

¹ Biometrika 8: 52-65. 1911.

² The number of pods per plant was weighted with the number of pods counted in calculating mean and standard deviation of number of pods. Sheppard's modification was nowhere applied, variation being by discrete units. The number of pods in which the number of ovules and seeds was determined was used as n in the calculation of the probable errors.

TABLE I
CONSTANTS FOR VARIOUS SERIES OF BEANS

Series	Number of Plants	Number of Pods Examined	Correlation: Pods per Plant and Ovaries per Pod	$\frac{r_{po}}{E r_{po}}$	Correlation: Pods per Plant and Seeds per Pod	$\frac{r_{ps}}{E r_{ps}}$	$\frac{r_{ps} - r_{po}}{\text{and Probable Error}}$	$\frac{r_{ps} - r_{po}}{E}$	Partial Correlation $\frac{\sigma^2_{ps}}{\sigma^2_{ps}}$	$\frac{\sigma^2_{ps}}{E \sigma^2_{ps}}$
L	185	1,804	.040 \pm .016	2.50	-.022 \pm .016	- 1.39	-.061 \pm .022	- 2.75	-.040 \pm .016	- 2.50
LL	1,141	8,043	.068 \pm .008	9.11	+ .050 \pm .008	+ 6.72	-.018 \pm .011	- 1.70	+ .028 \pm .008	+ 3.72
LG	182	806	.230 \pm .024	13.87	-.046 \pm .024	- 1.93	-.345 \pm .032	-10.79	-.082 \pm .024	- 3.48
GG	747	6,310	.023 \pm .008	2.76	-.028 \pm .008	- 3.35	-.051 \pm .012	- 4.35	-.035 \pm .008	- 4.12
GGH	583	5,251	.127 \pm .009	13.93	+ .135 \pm .009	+14.88	+ .009 \pm .013	+ .67	+ .087 \pm .009	+ 9.47
GGH ₂	499	3,502	.066 \pm .011	5.81	+ .104 \pm .010	+10.28	+ .038 \pm .015	+ 2.52	+ .082 \pm .011	+ 7.23
GGHH	396	2,656	.097 \pm .013	7.51	+ .096 \pm .012	+ 8.06	-.001 \pm .018	-.06	+ .056 \pm .013	+ 4.29
GCD	514	1,438	.124 \pm .018	7.09	+ .022 \pm .018	+ 1.27	-.102 \pm .025	- 4.10	-.024 \pm .018	- 1.37
GGD ₂	449	1,227	.124 \pm .019	6.57	+ .090 \pm .019	+ 4.72	-.035 \pm .027	- 1.30	+ .041 \pm .019	+ 2.13
GGDD	342	807	.074 \pm .024	3.14	+ .105 \pm .021	+ 4.96	-.031 \pm .032	+ .97	+ .083 \pm .024	+ 3.51
H	379	5,141	.200 \pm .009	22.22	+ .077 \pm .009	+ 8.21	-.123 \pm .013	- 9.45	-.013 \pm .009	- 1.41
HH	1,484	14,029	.263 \pm .005	49.58	+ .325 \pm .005	+64.96	+ .062 \pm .007	+ 8.61	+ .230 \pm .005	+42.60
HHH	1,271	11,230	.203 \pm .006	33.20	+ .206 \pm .006	+34.33	+ .004 \pm .009	+ .41	+ .135 \pm .006	+21.68
HD	1,416	5,581	.170 \pm .009	19.48	+ .019 \pm .009	+ 2.06	-.151 \pm .012	-12.18	-.058 \pm .009	- 6.50
HDD	1,204	5,449	.275 \pm .008	32.71	+ .161 \pm .009	+18.04	-.114 \pm .012	- 9.36	+ .028 \pm .009	+ 3.06
D	550	1,473	.355 \pm .015	23.20	+ .150 \pm .017	+ 8.75	-.205 \pm .023	- 8.97	-.044 \pm .018	- 2.54
DD	513	1,827	.320 \pm .014	22.67	+ .151 \pm .015	+ 9.83	-.168 \pm .021	- 8.10	-.009 \pm .016	- .57
DDD	459	2,018	.203 \pm .014	14.18	+ .185 \pm .014	+12.88	-.017 \pm .020	- .86	+ .109 \pm .015	+ 7.34
DH	670	5,955	.310 \pm .008	39.29	+ .338 \pm .008	+43.92	+ .028 \pm .011	+ 2.52	+ .211 \pm .008	+25.33
DHH	565	5,019	.243 \pm .009	27.29	+ .228 \pm .009	+25.33	-.015 \pm .013	- 1.18	+ .138 \pm .009	+14.76
USC	530	2,569	.181 \pm .013	14.14	+ .055 \pm .013	+ 4.23	-.126 \pm .018	- 6.98	-.006 \pm .013	-.43
USS	680	6,605	.151 \pm .008	18.20	+ .113 \pm .008	+13.63	-.038 \pm .012	- 3.25	+ .043 \pm .008	+ 5.22
USH	361	3,406	.242 \pm .010	22.44	+ .137 \pm .011	+12.15	-.105 \pm .016	- 6.74	+ .027 \pm .012	+ 2.37
USHH	224	1,743	.112 \pm .016	7.03	+ .010 \pm .016	+ 6.26	-.012 \pm .022	- .54	+ .063 \pm .016	+ 3.94
USD	312	802	.160 \pm .023	6.91	+ .028 \pm .024	+ 1.18	-.132 \pm .033	- 3.98	-.035 \pm .024	- 1.48
USDD	237	851	.319 \pm .021	15.41	+ .187 \pm .022	+ 8.39	-.132 \pm .030	- 4.34	+ .079 \pm .023	+ 3.43
FSC	586	2,876	.206 \pm .012	17.15	+ .112 \pm .012	+ 9.04	-.094 \pm .017	- 5.45	+ .045 \pm .013	+ 3.58
FSS	868	7,809	.204 \pm .007	27.88	+ .226 \pm .007	+31.42	+ .023 \pm .010	+ 2.23	+ .166 \pm .007	+22.43
FSH	475	4,541	.316 \pm .009	35.12	+ .251 \pm .009	+26.68	-.065 \pm .013	- 5.02	+ .126 \pm .010	+12.76
FSHH	427	3,837	.230 \pm .010	22.29	+ .197 \pm .011	+18.71	-.033 \pm .015	- 2.27	+ .117 \pm .011	+10.97
FSD	428	1,449	.265 \pm .016	16.16	+ .128 \pm .017	+ 7.36	-.137 \pm .024	- 5.76	+ .015 \pm .018	+ .87
FSDD	387	1,556	.267 \pm .016	16.87	+ .165 \pm .017	+ 9.94	-.102 \pm .023	- 4.44	+ .060 \pm .017	+ 3.55

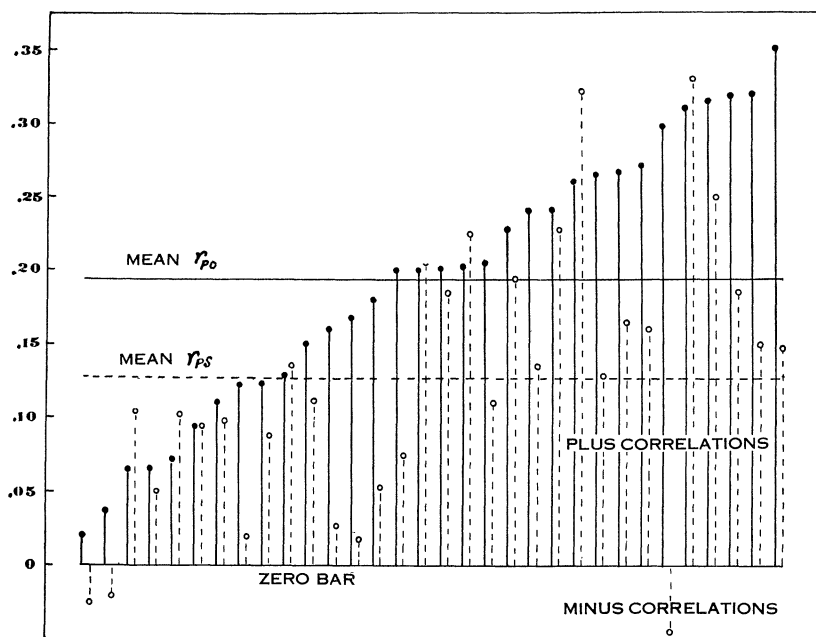


DIAGRAM 1. Magnitudes of correlations r_{po} and r_{ps} in 32 series of garden beans. The series are arranged in order of magnitude of r_{po} : r_{po} = solid lines and dots; r_{ps} = broken lines and circles; \bar{r}_{po} = solid bar; \bar{r}_{ps} = broken bar.

lidity of r as a measure of interdependence. It is of interest and importance biologically, since it shows whether the rate of modification of an associated character changes from one end to the other of the range of variation of the independent variable.

The labor involved in testing graphically the agreement of theoretical and empirical means for all of the series is prohibitive. Other methods of dealing with the problem are, as will be clear in a moment, unfavorable. I have, therefore, contented myself with the graphical treatment of a few illustrative cases (table II and diagrams 2 and 3).

In the graphs the means for the full range of variation in number of pods per plant has not been shown.³ This arises from the fact that

³ The observed range of variation in number of pods per plant is indicated in the table. Limitations of space preclude the drawing of a scale for the means of ovules and seeds for each line, but it is the same for all and may be estimated fairly well by the reader from the end points of the lines as given in the table.

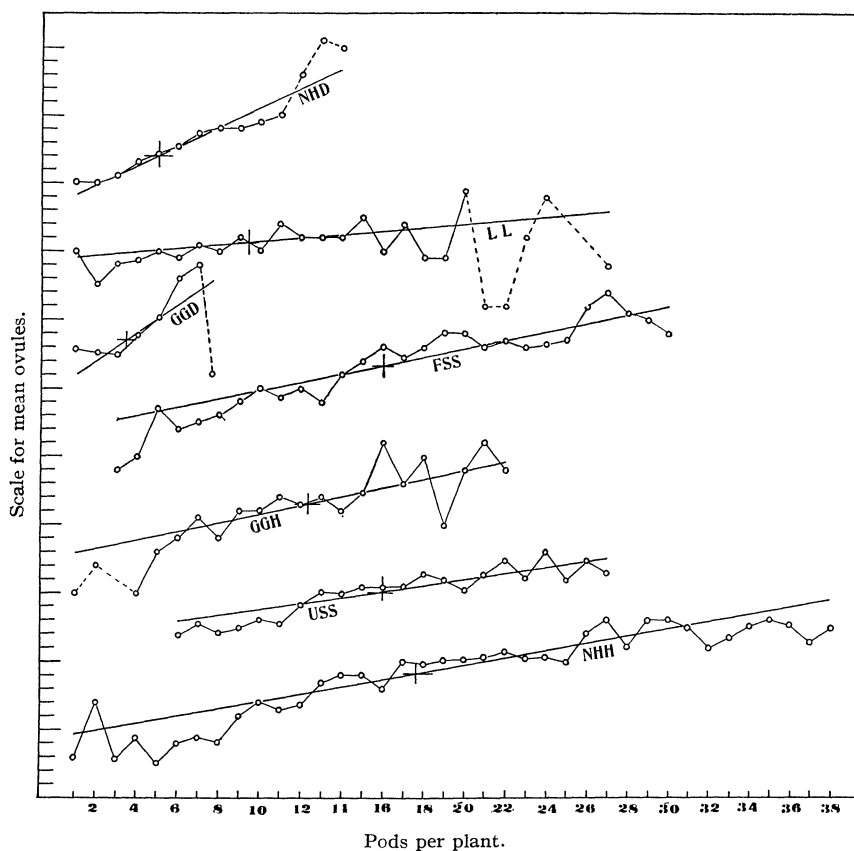


DIAGRAM 2. Regression of ovules per pod on number of pods per plant. The end points of the lines are given in the table.

variation in the number of pods is very great ⁴ and that in consequence the extreme cases are represented by very few individuals. Thus in the HH series the number of pods per plant ranges from 1 to 67, but of the

⁴ The coefficients of variation for the number of pods per plant (unweighted) for the series illustrated in the graphs are:

HH = 51.02	FSS = 49.34
HD = 48.97	GGD = 44.07
GGH = 38.60	LL = 58.55
USS = 38.36	
	Mean = 46.99

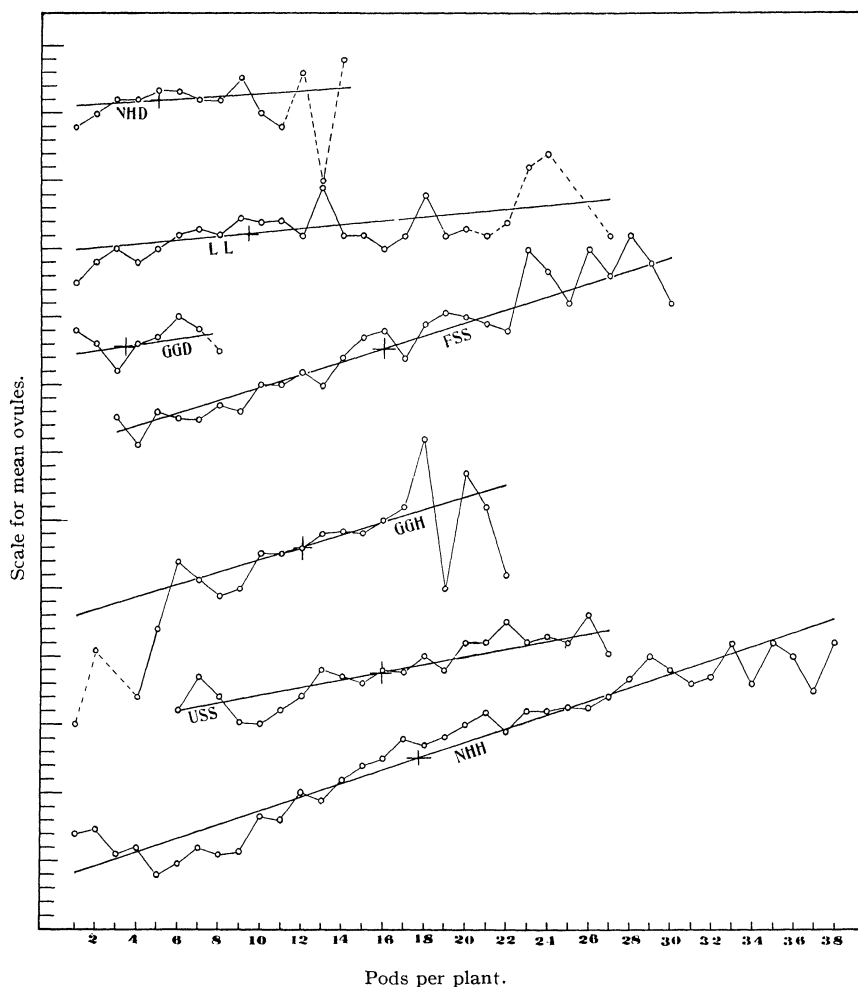


DIAGRAM 3. Regression of seeds matured per pod on number of pods per plant.

1,484 plants there are only 36 which produce more than 38 pods. To calculate means for arrays of such sizes is idle. Neither is it desirable, in view of the great differences in the range of variation from series to series, to combine classes in order to secure larger arrays. Any objections based on the fewness of individuals in the arrays applicable to

TABLE II
EQUATIONS FOR REGRESSION OF OVULES PER POD AND SEEDS PER POD ON
NUMBER OF PODS PER PLANT

Series	Regression Equation	End Points of Line	Range of Pods
HH	$o = 4.940 + .027 p$	$I = 4.97, 38 = 5.96$	I-67
HH	$s = 3.388 + .050 p$	$I = 3.44, 38 = 5.28$	I-67
HD	$o = 4.375 + .070 p$	$I = 4.44, 14 = 5.35$	I-14
HD	$s = 3.072 + .011 p$	$I = 3.08, 14 = 3.23$	I-14
GGH	$o = 5.300 + .031 p$	$I = 5.33, 22 = 5.99$	I-33
GGH	$s = 3.743 + .046 p$	$I = 3.79, 22 = 4.76$	I-33
USS	$o = 5.173 + .022 p$	$6 = 5.31, 27 = 5.77$	I-50
USS	$s = 3.457 + .026 p$	$6 = 3.62, 27 = 4.17$	I-50
FSS	$o = 5.202 + .030 p$	$3 = 5.23, 30 = 6.11$	I-54
FSS	$s = 2.536 + .047 p$	$3 = 2.58, 30 = 3.95$	I-54
GGD	$o = 4.561 + .089 p$	$I = 4.65, 8 = 5.27$	I-8
GGD	$s = 2.709 + .022 p$	$I = 2.73, 8 = 2.88$	I-8
LL	$o = 4.950 + .013 p$	$I = 4.96, 27 = 5.30$	I-27
LL	$s = 2.515 + .014 p$	$I = 2.53, 27 = 2.88$	I-27

graphical methods of testing for linearity are equally valid, or even stronger, for formal tests, for example those based on a comparison of r and η . For 0 correlation η may have a substantial value when the arrays are numerous; it is in just such cases as this that very misleading results might be obtained through a careless application of Blakeman's test.

In the graphs the theoretical lines are drawn according to the equations calculated from the whole material, but are not extended beyond classes of pods per plant represented by only five individual plants or fewer.

The slope of all the lines is slight and the scatter of the empirical means decidedly large. This is precisely the condition to be expected in widely varying and but slightly correlated characters. For the benefit of those who may not be familiar with either the biological or the statistical phases of the study it may be pointed out that the irregularities seen in these diagrams are neither due to carelessness in the biological experiments nor to inadequacies of the statistical methods, but solely to the difficulties inherent in the material.

With regard to the critical question, that of the sensible linearity or non-linearity of the empirical means, the diagrams do not—and largely because of this great irregularity—furnish a final answer. But while there is some indication of significant non-linearity, for practical purposes a straight line describes the change in o and s associated with an increase in p with sufficient accuracy.

Having justified the use of r^5 as a constant describing the degree of interdependence between p and o and s , I turn to the constants themselves.

The correlations are conspicuous for their irregularity. Practically speaking, however, they are positive throughout. This is strictly true for the relationship between pods per plant and ovules per pod. It holds for 29 of the 32 measures of the relationship between pods per plant and seeds per pod; of the 3 negative correlations all are small and neither can be safely regarded as statistically trustworthy with regard to its probable error.

Computing the physical constants of these varying values of correlation I find

	r_{po}	r_{ps}
Mean.1948 \pm .0107	.1264 \pm .0109
Standard deviation.0899 \pm .0075	.0915 \pm .0077
Coefficient of variation.46.16	72.38

The relationship between number of pods and ovules per pod is apparently higher than that between the number of pods and the number of seeds matured. The first of these may be considered a more strictly morphogenetic relationship, the second a more truly physiological one. The difference, .0684 \pm .0153, is nearly four and a half times its probable error, and so perhaps significant.

Further evidence may be obtained upon the problem of the relative values of the two correlations by considering the differences in the two constants for each experiment separately, as shown in table I. In 7 cases $r_{ps} > r_{po}$, but in 25 cases $r_{po} > r_{ps}$. Taking the ratio of the differences to their probable errors, it appears that 3 of the cases in which the correlation for seeds is higher than that for ovules may possibly be considered significant (> 2.5) while there are 18 cases in which the correlation for ovules is higher than that may be taken to be trustworthy statistically. The mean value of the ratios of the positive differences, $r_{ps} > r_{po}$, to their probable errors is 2.56, while that for the negative differences is 4.96.

It is, therefore, clearly demonstrated that although the values of the correlations are both low and irregular, those measuring the relationship between the number of pods and the number of ovules are sensibly higher than those measuring the relationship between the number of pods and the number of seeds matured per pod.

⁵ Even if regression is not strictly linear, r is the best constant to be used, since η would be too largely affected by the errors of sampling in the numerous small arrays.

There can be little doubt that the observed statistical correlation between the number of pods per plant and the number of ovules laid down per pod describes a real morphogenetic interdependence. The constants further show that the relationship for the particular characters under consideration is not strict but lax.

The biological interpretation of the numerical values for number of pods and number of seeds matured per pod is not so simple. Here a second set of innate and environmental physiological factors—those involved in determining whether a given ovule shall die or develop—are superimposed upon the morphogenetic and physiological complex involved in determining the degree of development of p and o .

The most patent effect of these superimposed physiological factors is the death (non-development) of a considerable proportion of the ovules. The number failing to develop into seeds varies widely from pod to pod, but on the average it is roughly, though as I have shown (1913*e*) not exactly proportional to the number of ovules per pod. As a result there is a correlation of medium intensity between the number of seeds developing per pod and number of ovules formed (1912*d*).

Clearly, therefore, there may be (at least) two quite independent sets of factors influencing the correlation between p and s . The first of these is involved in the interdependences r_{po} and r_{os} ; as a resultant of these forces some relationship must exist between p and s . It is conceivable that this correlation which indicates no direct and independent physiological or morphogenetic nexus between p and s may account for the whole of the observed value of r_{ps} .

To correct for the influence of r_{po} and r_{os} on r_{ps} , I have recourse to the partial correlations between pods per plant and seeds per pod for constant numbers of ovules per pod. These have been calculated from the usual formula

$${}_o r_{ps} = \frac{r_{ps} - r_{po} r_{os}}{\sqrt{1 - r_{po}^2} \sqrt{1 - r_{os}^2}}$$

for each of the series. The values for r_{po} , r_{ps} are of course those of this paper. Those for r_{os} have already been published (1912*d*).

The values, table I, are also shown graphically in comparison with the correlations r_{ps} in diagram 4. The reduction in the intensity of the relationship between number of pods and number of seeds when correction is made for the relationship of these two characters with number of ovules per pod is clearly marked: it occurs in every in-

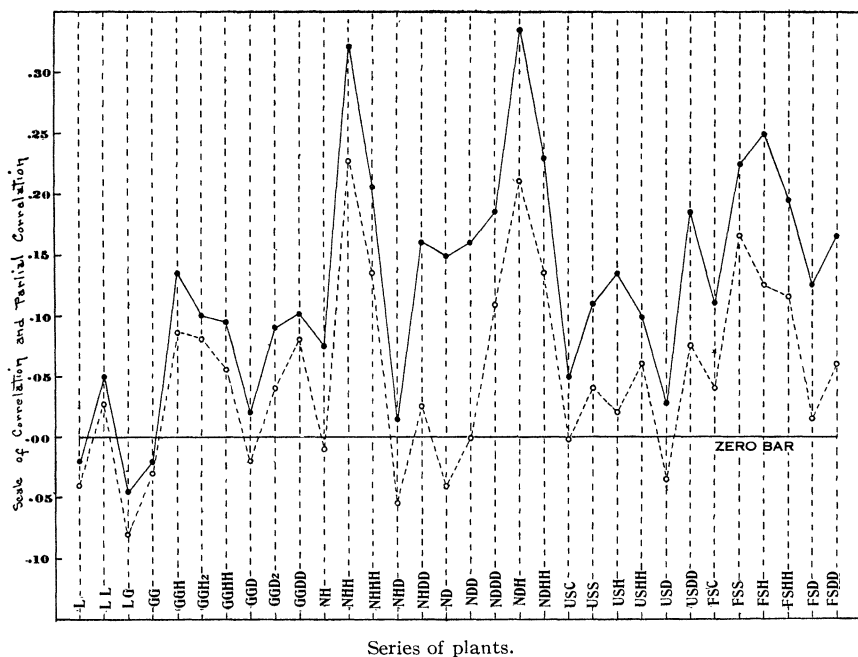


DIAGRAM 4. Comparison of the correlations r_{ps} (solid dots and firm line) and the partial correlations $o r_{ps}$ (circles and broken line) for individual series.

dividual case; only 3 of the values of r_{ps} have the negative sign while 10 of the partial correlation coefficients, $o r_{ps}$, fall below the zero bar: $\bar{r}_{ps} = .1264 \pm .0109$, $\bar{o r}_{ps} = .0507 \pm .0090$.

Notwithstanding the material reduction in r_{ps} when correction is made for the influence of r_{po} , r_{os} there seems to be a residuum of interdependence which cannot be thus accounted for. Evidence for this conclusion is seen in four facts. (a) The mean partial correlation has a positive and perhaps significantly positive value: $\bar{o r}_{ps} = .0507 \pm .0090$, $\bar{o r}_{ps}/E \bar{o r}_{ps} = 5.64$. (b) Of the individual values of $o r_{ps}$ only 10 of the 32 are negative in sign. (c) The mean value of the negative coefficients is only $-.0347$ while that of the positive constants is $+.0895$. (d) Of the 10 negative coefficients 5 may perhaps be considered statistically significant with regard to their probable error, although this number would be reduced if n were taken as plants instead of pods in the calculation of the probable error. Of the positive

coefficients 19 are over 2.5 times their probable error, as compared with the 5 possibly significant values noted for the negative. Furthermore, the mean of the ratios of the 10 negative coefficients to their probable error is only 2.49 as compared with a mean ratio of 9.74 for the positive coefficients.

Thus the evidence seems to justify fully the assertion that there is a slight physiological relationship between the number of pods which a plant produces and the number of seeds which it is capable of maturing in these pods, and that this relationship is quantitatively independent of the more strictly morphogenetic factors linking together number of pods and number of ovules per pod.

Further than this the analysis cannot safely be pushed on the basis of available data.

III. COMPARISON OF THE FOREGOING CONSTANTS WITH OTHER CORRELATIONS FOR SOMATIC CHARACTERS AND FERTILITY

Since many additional series of data bearing on these problems are in hand and will eventually be published, I shall not compare in detail the results set forth here with others but I shall indicate merely the order of correlations which have been found.

For length of flowering stalk and number of flowers in the umbel-like inflorescence of two liliaceous plants the correlations are roundly⁶

For *Nothoscordium striatum*, $r = .500$,

For *Allium stellatum*, $r = .620$.

For the relationship between the length of the flowering stalk (pedicel) and number of ovules and seeds per fruit the only available data are⁷

For *Sanguinaria*, $r_{lo} = .323 \pm .019$,

For *Sanguinaria*, $r_{ls} = .363 \pm .019$.

Here $r_{ls} > r_{lo}$, but $r_{ls} - r_{lo} = .040 \pm .027$ only. Thus the difference is hardly significant with regard to its probable error; there is only a single series of material; further collections might show that here, as in garden beans, the correlation for degree of vegetative development and number of seeds is on the average lower than that for vegetative development and number of ovules per pod. The partial correlation in the case of *Sanguinaria* would of course have a significantly positive value.

⁶ Ann. Rept. Mo. Bot. Gard. 20: 105-115. 1909.

⁷ Biometrika 7: 316. 1910.

In these three cases the bulb or rootstock sends up only a single inflorescence. The correlation for length and ovules and seeds in *Sanguinaria* is much closer to the r_{po} and r_{ps} in beans than are the correlations in *Nothoscordium* and *Allium*. This is perhaps to be expected, since in the two Liliaceae the correlation is between the length of a main axis and the number of secondary axes originating from it, while in *Sanguinaria* and in the beans the correlation is (roughly speaking) between the degree of development of the axis and the characteristics of the ovaries which it produces.

That the correlations in *Sanguinaria* are sensibly higher than the average values for beans may be due in part to chance—a few of the values for beans reaching almost the magnitude of those found in the blood-root. It is perhaps more probable that the higher value in *Sanguinaria* is due to the facts (a) that the correlation is between two intimately associated organs—a single fruit terminating the simple axis the length of which furnishes the measure of the degree of somatic development, whereas in garden beans the axis is extensively divided—and (b) that *Sanguinaria* is a perennial and there is doubtless considerable age heterogeneity which probably tends to raise the correlation.

If one extends the range of comparison to include the relationships within inflorescences there are several available constants.

In *Crinum longifolium*⁸ I have found for fruits per inflorescence and seeds per fruit, $r_{fs} = -.072 \pm .024$. For the inflorescence of *Celastrus scandens*⁹ I have shown

For flowers and seeds, $r = .033 \pm .013$,

For fruits and seeds, $r = -.012 \pm .013$.

In *Staphylea* the correlation between number of fruits per inflorescence and number of ovules and seeds per pod has been investigated¹⁰ for series of individual shrubs, as well as for random collections from numbers of shrubs. It is difficult in these cases to be sure of even the sign of the correlation. The correlation for number of fruits and length of fruit is low.¹¹ Those for number of fruits and radial asymmetry and locular composition are also very small.¹²

For three series of intact inflorescences from individual trees of the legume *Cercis canadensis* in which the number of ovules in the ovaries

⁸ Ann. Rept. Mo. Bot. Gard. **23**: 89-91. 1912.

⁹ Ann. Rept. Mo. Bot. Gard. **20**: 120-122. 1909.

¹⁰ Beih. Bot. Centralbl., Abt. I, **28**: 2-10. 1911.

¹¹ Bot. Gaz. **53**: 401-402. 1912.

¹² Zeitschr. Ind. Abst.- u. Vererbungslehre **5**: 183-187. 1911.

was determined by clearing with alcohol and counting under the microscope, the results are¹³

Tree 1, $r = -.007 \pm .023$,

Tree 2, $r = .030 \pm .021$,

Tree 3, $r = .134 \pm .024$,

where the probable errors are calculated on the basis of the number of ovaries dissected out and examined, not the number of inflorescences.

Thus the correlations between the number of flowers formed or number of fruits matured per inflorescence and the fertility of the fruits—either as measured by the number of ovules laid down or the number of seeds ripened—are without exception very low indeed.

IV. SUMMARY AND DISCUSSION

This paper, which is one of a series on the various aspects of fertility and fecundity in plants, is a contribution of data towards the solution of the problem of the relationship between the degree of somatic development of the plant individual as measured by the number of fruits which it bears, and the fertility of these fruits as measured by the number of ovules formed and the number of seeds developing.

The data comprise the records of number of ovules formed and number of seeds matured in 127,610 pods of garden beans, *Phaseolus vulgaris*, from 19,064 plants with known number of pods drawn from 32 cultures made under a wide range of environmental conditions and embracing five different varieties.

Taken in connection with data recorded in other papers they permit the consideration of points not touched upon here. It is perhaps fair to state that these are to be discussed in subsequent papers where extensive additional series of records already in hand can be reduced.

The analyses of the data as far as carried out lead to the following conclusions:

(1) The correlation between number of pods per plant and number of ovules per pod has always been found positive but low, ranging from .023 to .355, with an average value of about $\bar{r}_{po} = .195$.

(2) For pods per plant and seeds per pod the correlations are also for the most part positive, although constants which have the negative sign but are insignificant with regard to their probable errors sometimes occur.

These values range from—.046 to .338 with a mean of $\bar{r}_{ps} = .126$.

¹³ Bot. Gaz. 53: 403-404. 1912.

By all available tests the coefficients for pods per plant and ovules per pod seem to be significantly higher than those for pods per plant and seeds per pod.

(3) As a resultant of the relationship between pods per plant and ovules per pod (r_{po}) and that demonstrated elsewhere between ovules and seeds per pod (r_{os}) some correlation must be expected between number of pods per plant and number of seeds per pod, whether there be any direct physiological interdependence between these two characters or not.

(4) By determining the correlation between p and s for constant values of o , i , e , by calculating or_{ps} by the usual partial correlation formulae for three variables, I have tried to remove the influence of the interrelationships of o , p and s upon the coefficient r_{ps} .

(5) All the coefficients measuring the relationship between number of pods and number of seeds are lowered by thus correcting for r_{po} and r_{os} , that is $or_{ps} < r_{ps}$, always. Several of the partial correlations have the negative sign. Their mean value while very small, $or_{ps} = +.051$, is apparently significantly positive.

(6) Thus on the average, there is some correlation between the numbers of pods per plant and the number of ovules which develop into seeds which is in part at least independent of—although it may be inseparably bound up with—the morphogenetic factors which link together the magnitudes of the two characters p and o . This correlation which must have its origin in the factors underlying the fertilization of the ovule and its nutrition during the period of growth into a seed, I have ventured to designate as more truly physiological, although there is probably in reality no sharp line of demarcation between physiological and morphogenetic in problems of the kind under consideration here.

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